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Lord Rayleigh has been engaged upon a study of the silver voltameter and its application to the measurement of electrical currents. He finds that one ampère deposits four grams of silver per hour, and a sufficient amount can therefore be obtained for accurate weighing in fifteen minutes. Pure nitrate or chlorate of silver gives the best results. Beetz has proposed a new form of Daniell cell, of great internal resistance. Fine alabaster plaster-of-Paris is mixed with concentrated sulphate-of-copper solution, and the copper electrode is fixed in this at one end of a glass tube: the rest of the tube is filled with concentrated sulphate of zinc and plaster-of-Paris, and the zinc electrode is also embedded in this. The ends of the tube are filled with paraffine. This form of cell has been tried at the Jefferson physical laboratory of Harvard university, and has been found an excellent substitute for the water-cell of zinc and copper for charging electrometers.

The lull in the progress of theoretical electricity is probably the precursor of important additions to our knowledge; for many investigators are at work, both at home and abroad, testing the new electrodynamic theory of light, and adding to our knowledge of magnetism. The equipment of physical laboratories in America, which has been one of the features of the year at Cambridge as well as elsewhere in America, bids us hope for much systematic study of the science of electricity, and physical science in general. JOHN TROWBRIDGE.

CO-ORDINATION OF THE SCIENTIFIC BUREAUS OF THE GOVERNMENT.¹

THE land-maps of European countries are, as a rule, made under the direction of the war departments of those countries, and under the direction of officers of the army specially detailed for that duty, with the aid of experts in the business and in the arts necessary to the surveys and to the production of the charts, who are employed from civil life, and also of enlisted soldiers and non-commissioned officers detailed from the army.

For details on this subject, the committee refers to the printed notes on European surveys compiled and published in 1876, under the direction of one of its members, Gen. C. B. Comstock, U. S. engineers, as the most complete compendium on this subject known to them; also to some manuscript notes prepared by the committee from reports and publications of later date.

¹ Extracts from the report of a committee of the National academy of sciences, consisting of Gen. MEIGS, and Professors J. P. TROWBRIDGE, PICKERING, YOUNG, WALKER, and LANGLEY.

The hydrographic surveys of the coasts of Europe appear in every country to be the work of the naval establishment. On the coasts of the United Kingdom the hydrography has been completed; and now two parties in surveying vessels of the navy are constantly employed in re-sounding and examining channels, harbors, and shoals, in order to correct the existing admiralty charts. All this is done under direction of the admiralty.

While the organization of the land and of the hydrographic surveys in Europe are very perfect, your committee does not find that they offer any thing to improve that of the United States, except, perhaps, in showing the economy in time and money of greater use of photography and of zincography in the reduction and production of maps and charts. In Great Britain now the twenty-five-inch-to-the-mile map is published even earlier than those on smaller scales, all of which are reductions from the original manuscript maps surveyed and plotted on the twenty-five-inch or six-inch scale.

Early and cheap publications of results of operations in the field, if they retain the accuracy of the original maps, are of great industrial and economic importance. The English maps of the ordnance survey are published and placed on sale as soon as printed, and at very moderate prices.

Your committee would call attention, in this connection, to the report made by the National academy of sciences to congress in December, 1878, in which the advantages of a consolidation of the then existing surveys were pointed out. In that report, it was recommended that surveys should be two in number, — the coast and interior survey, to be concerned with the triangulation and mapping of the country and its topography; and a geological survey, to undertake geological and economical investigations. It would be a part of the duty of the former survey to supply the maps for the use of the geological survey; and, in order to secure the co-ordination and harmonious co-operation of the two surveys, it was recommended that the coast and interior survey be transferred to the interior department.

Congress adopted so much of this recommendation as related to the formation of a single geological survey, but did not provide for the proposed transfer of the coast-survey, nor make any other provision for the topographic work necessary for the geological survey. The result has been that these two surveys do not co-operate as they should. The chief of the geological survey has also found it necessary to employ large corps of men in trigonometric measurements.

Your committee does not feel entire confidence that the union of these two surveys under either one of the executive departments, would, without other measures, necessarily lead to that unity of work which is desirable. It therefore recommends certain further legislative measures, the occasion for which will be made clear by a review of the work done by these several organizations; but its members are entirely clear in the opinion that some one of the executive departments should control both. It is for

congress to determine which department shall exercise this necessary authority and control.

The coast-survey was originally organized for the purpose of constructing maps and charts of the coast and harbors for the benefit of commerce and navigation. Conflicting opinions respecting the proper management of the survey led to the formation, in 1843, of a board of officers with the duty of re-organizing the survey. This board submitted a plan which was enacted by congress into law, upon and under which law the survey has hitherto been executed. This plan provided for the co-operation of military officers, naval officers, and civilians in the various parts of the work. Under it the work of the coast-survey has been continued to the present time.

In recent times a great extension of the field of operations of the survey has been made, apparently looking to a triangulation covering the entire territory of the United States. The maps published annually with the report of the survey enable us to know the geodetic work it has executed. It appears, from the maps accompanying the report of 1882, that on June 30 of that year a chain of triangles had been extended throughout the entire length of the Atlantic and Gulf coasts, and throughout about half the Pacific coast. Besides these coast-lines, extensive regions in the interior are seen to be triangulated. In the north-east, the triangulation covers the greater part of the states of New Hampshire, Vermont, and Massachusetts, about half of Connecticut, and it also includes a considerable part of the state of New York.

The reconnoissance has extended westward from the New-Jersey coast, so as to include the greater part of the state of New Jersey, and a long strip in Pennsylvania. From Pennsylvania, the extended line of primary triangulation follows the Allegheny Mountains into northern Alabama, and is now being continued across the country to Memphis.

A triangulation of the Mississippi River was extended from its mouth nearly to Memphis, where it would meet the last-described chain of triangles. The chain connecting the Atlantic and Pacific coasts has been completed nearly across the state of Nevada, and the reconnoissance includes nearly half of Utah Territory. The line is also surveyed at various points in Colorado, Kansas, Missouri, and Illinois. Besides all this, isolated regions in Wisconsin, Indiana, Illinois, Ohio, Kentucky, and Tennessee, have been reconnoitred by the coast and geodetic survey, in a way indicative of a plan designed ultimately to cover the entire territory. As its appropriations for some years past have made provision for the collection of data for a general map of the United States, we may fairly regard the coast and geodetic survey as having undertaken a trigonometric survey of the whole United States.

From the statement of the director of the geological survey, we learn, that, under authority of the annual appropriation bills to prepare a geological map of the United States, that officer has parties engaged in the trigonometric survey of the entire country, which is to be sufficiently accurate for car-

tographic purposes. It appears, therefore, that two distinct and independent trigonometric surveys of the United States, under two different departments of the government, are now in process of execution.

The meteorological work of the signal-service is divisible into two distinct branches. The first and by far the larger portion of the work is the collection of weather reports from stations in different parts of the union, which are utilized in predicting the probable weather during the twenty-four hours succeeding. Connected with this work is the publication of weather maps, showing at a glance the state of the weather over the entire country at certain moments of absolute time. At the school at Fort Myer, observers and operators are trained for this service. A very important part of its work is the display of signals, and warnings of approaching storms, frosts, and floods.

The other branch of the meteorological service appears in scientific discussions and investigations having for their object the advance of the science of meteorology. These researches are published under the title, 'Professional papers of the signal-service,' which papers consist of memoirs separately paged, and numbered in the order of their issue. Your committee is not informed of the separate expenses of these two divisions of the signal-service, but has no doubt that the expense of the second branch is but a small fraction of that of the first.

The signal-service also performs a military duty, providing the material, and instructing soldiers and officers to communicate between separate bodies of troops by a system of day and night signals; and it also operates and repairs, and when necessary constructs, telegraph-lines for military purposes. The appropriation for these military works and services for the current year is five thousand dollars. In the opinion of the committee, it is desirable that the meteorological work of the weather bureau should be under the general control of the commission proposed later in this paper.

The hydrographic office of the navy department may be considered to date from the year 1848, when the depot for charts and instruments for the navy, authorized by an act approved in 1842, was established. Under this act an observatory was established, and was engaged in the double work of making astronomical observations, correcting chronometers, and of supplying charts to the navy; the establishment being officially styled 'the U. S. naval observatory and hydrographic office.' In 1866 congress authorized the establishment of a separate hydrographic office, to be attached to the bureau of navigation in the navy department, for the purpose of supplying nautical publications and information, not only to vessels of the United States, but to navigators generally. Before that time the functions of the office had been confined to the purchase and distribution of foreign charts. Under the new organization, a drawing and engraving division was established, which constructs charts of foreign coasts and seas for distribution to vessels of the navy, and for sale, at the cost of printing and paper, to navigators gener-

ally. The officer now in charge of the hydrographic office appeared before your committee in person, and gave it a very clear account of the work his office is actually doing.

Besides the hydrographic work of the coast-survey, — which is conducted, and has always been conducted under existing laws, under the direction of the superintendent of the coast-survey, — this hydrographic office is not only supplying corrected charts to the vessels of the navy, but is collecting information as to ice which endangers every ship or steamer of the great lines which connect our northern ports with Great Britain and France; and it also publishes constantly information as to changes in lights and buoys, and discoveries by all nations of shoals and dangers not laid down upon the charts in common use. It publishes at short intervals, not only printed information by bulletin sent to commercial centres in this country, but pilot charts, especially of the North Atlantic, giving the latest intelligence in regard to currents and winds, and the location, when last seen, of all floating wrecks and derelicts, and of the icebergs and other floating ice which through the whole spring, summer, and fall seasons, lie along the eastern edge of the Great Banks, directly in the track followed by hundreds of steamers and sailing-vessels, carrying many thousands of travellers, passengers, and immigrants, and the millions of dollars of our exports and imports.

This work of the hydrographic office is evidently of great value and importance to our commercial and business interests, and must save many vessels from wreck, and many lives from destruction. Naval vessels under direction and instruction of the hydrographic office also survey foreign coasts and unsurveyed harbors and channels, aiding powerfully in the extension and introduction of our commerce to such coasts and harbors; and they contribute to the knowledge of the earth and its inhabitants by deep-sea soundings, by observations of the currents and winds and storms, and of the bottom of the ocean and of its shores.

While this work is scientific work, your committee is not prepared to recommend that it be detached in any way from the control of the navy department; nor can they recommend that the hydrographic work of the coast-survey, for over forty years conducted so satisfactorily under the civil control of the coast-survey, be separated from that organization before the original survey shall be completed. After that is done, perhaps the work of re-sounding and of re-examining may, without injury to the service, be committed to the control of the navy department. Yet even then correction and revision of the coast-survey charts will require some co-ordination, some authoritative connection between the coast-survey office and the parties and vessels engaged in these re-examinations for correction of our coast charts.

From the terms of the act under which your committee is considering this subject, it may be inferred that the principal question affecting the hydrographic office, on which an opinion is desired, is that of its consolidation with the hydrographic work of the

coast-survey. The reasons for the consolidation of these two works under the navy department have been urged with force by the secretary of the navy in his last two annual reports. But there are also cogent reasons on the other side of this question. The coast-survey was specially organized to secure the harmonious co-operation of civilians, officers of the navy, and officers of the army, each in his own department, and yet in a single well co-ordinated work. No scientific department of the government has worked more successfully through the forty years in which this organization has been in operation. Each of the three branches thus harmoniously co-operating has received the benefit of the skill and professional experience of the other.

An organization of this sort should not, while its work is going on, be disrupted, except for very strong reasons affecting its efficiency. We would also advert, in illustration of the advantages which our military and naval officers have derived from their connection with the coast-survey, to the brilliant list of military and naval men during the civil war, who derived a very important part of their professional training from their experience on that work. Such a list would include an array of professional leaders which it would be difficult to collect from any other associated body of men. We suggest the names of Porter, the Rodgerses, of Meade, and of Humphreys. Many others might be added, who, after service on the coast-survey, rose to high employments in the army and navy.

While, therefore, your committee is not prepared at the present time to recommend the proposed consolidation, it does not conceive that congress should adopt measures looking to the separation in perpetuity of the two branches under consideration. The policy of the coast-survey should, we conceive, be directed towards the completion at the earliest possible date of the survey of our coast-line. Its main operations will thereafter be confined principally to the interior, and then the policy of consolidating its hydrography with the work of the naval hydrographic office will be open for consideration. We are therefore of opinion that the hydrographic office of the navy department is worked with all due efficiency as it is now organized, and that no change is at present necessary in its relations to the government.

Preliminary to our recommendations as to the other three works upon which your committee is called upon to report, it desires to present some general views respecting the working of the departments of the government. We conceive it desirable that there should be a clear understanding as to what sorts of scientific investigation may be undertaken by government organizations. We conceive it to be a sound principle that congress should not undertake any work which can be equally well done by the enterprise of individual investigators. Our leading universities are constantly increasing the means of scientific research by their professors and students; and, while the government may with propriety encourage and co-operate with them, there is no reason

why it should compete with them. The scientific work of the government ought not, therefore, to be such as can be undertaken by individuals. It should also be confined to the increase and systematization of knowledge tending 'to promote the general welfare' of the country. Within these two restrictions there is a large and increasing field, which is only partly occupied by the organizations now under consideration. In considering the limits of its functions, your committee, as one of scientists and not of constitutional lawyers, naturally confines itself to considerations affecting the general welfare.

The general government having commenced a general trigonometrical survey of the United States on a large scale, under organizations much more efficient in their action than those which any single state can provide, we conceive it desirable that the work thus undertaken should be continued at least to the point at which it can be advantageously taken up by the states themselves. At what precise limit the general government should stop, we are not prepared to decide, nor is it necessary that this limit should be defined at present. The attention of congress should also be directed to the fact that the administration of a scientific bureau or department involves greater difficulties than that of a purely business department. The connections between the work done and the results ultimately to be attained for the public are not at all obvious to the people and press, and thus the great benefit of vigilant watching and constant criticism is wanting. Again: its administration requires a combination of scientific knowledge with administrative ability, which is more difficult to command than either of these qualities separately. These difficulties are intensified by the absence of any central authority to control the work of a government scientific organization. Each head of a scientific organization is now practically absolutely independent, and, in his individual judgment of what his organization shall do, is controlled only by congress itself, acting only through its annual appropriation bills. We conceive that this state of things calls for measures of reform.

A feature of such reform will be the collection of the organizations now under consideration, together with such other scientific bureaus as congress may see fit to include in the scheme, under one central authority, to be recognized as responsible for, and controlling generally, the scientific operations of the government. Various forms of such an authority might be devised, the choice of which will some day be made by congress. The best form would be, perhaps, the establishment of a 'department of science,' the head of which should be an administrator familiar with scientific affairs, but not necessarily an investigator in any special branch.

Your committee states only the general sentiment and wish of men of science, when it says that its members believe the time is near when the country will demand the institution of a branch of the executive government devoted especially to the direction and control of all the purely scientific work of the government. In this day the pursuit of science itself

is, visibly to all men of education, directly connected with the promotion of the general welfare. The art of photography, beginning in 1802 with the scientific experiments of Wedgwood, has developed, till, in this country alone, the annual value of photographs produced is estimated at thirty millions of dollars. The study of electricity has resulted in the telegraph, the telephone, the electric light, the electric railway; some of which results count their revenue by millions, and have created already, within a few years of their discovery, properties employing the capital of hundreds of millions. None who have lived with open eyes during the development of these results of purely scientific investigation doubt that the cultivation of science 'promotes the general welfare.'

Should such a department be now impracticable, should public opinion not be now ready for it, the next best measure, in the opinion of scientific men, would be to transfer all such work or bureaus to some one executive department. Keeping in mind what has been said respecting the two classes of work under the signal-service, we are of opinion that the functions of the several organizations under consideration could now be most advantageously divided among perhaps four bureaus; namely,—

1°. The coast and interior survey, to be concerned principally with geodesy and hydrography, and to consist of the present coast and geodetic survey.

2°. The geological survey, to comprise the present geological survey with its organization unchanged.

3°. The meteorological bureau, to which should be transferred so much of the present *personnel* and functions of the chief signal-office as are not necessary to the military duties of that office.

4°. A physical observatory, to investigate the laws of solar and terrestrial radiation, and their application to meteorology, with such other investigations in exact science as the government might assign to it. In this connection, attention is called to a resolution passed by the recent electrical conference in Philadelphia, requesting the establishment, by the government, of a bureau of electrical standards. We are of opinion that the functions of the bureau of weights and measures, now performed by the coast-survey, could be advantageously transferred to the proposed bureau, and extended so as to include electrical measures.

The members of your committee are conscious that placing these bureaus under one department would not necessarily result in the proper co-ordination of their work, because the head of such department would probably find it impracticable to enter into the consideration of all details necessary to that purpose. It appears to us that the evils already pointed out require, in any case, the organization of a permanent commission to prescribe a general policy for each of these bureaus. The functions of this commission would be:—

1°. To examine, improve, and approve the plans of work proposed by the several bureaus, and to revise their estimates in accordance with such plan. The performance of this duty would require consultation with their chiefs generally and separately respecting

the character of their work, and they should be members of the commission.

2°. To approve in detail the methods of expenditure of the appropriations.

3°. To recommend such measures as they deem necessary to the efficiency of the bureaus under their supervision. It should, however, be understood that this commission is not charged with purely administrative responsibility. It prescribes what shall be done, and recommends any measures necessary to secure that object, but does not concern itself with administrative details.

We submit the following as a suggestion for the formation and *personnel* of such a commission:—

The commission shall consist of, 1°, the president of the National academy of sciences; 2°, the secretary of the Smithsonian institution; 3° and 4°, two civilians of high scientific reputation, not otherwise in the government service, to be appointed by the president of the United States for the term of six years; 5°, one officer of the corps of engineers of the army; 6°, one professor of mathematics in the navy, skilled in astronomy, — these two to be designated by the president of the United States for a term of six years, — who, with, 7°, the superintendent of the coast and geodetic survey; 8°, the director of the geological survey; and, 9°, the officer in charge of the meteorological service, — shall constitute the commission of ——. The secretary of the —— department shall be *ex-officio* president of the commission.

The members of the commission, for their services as such, shall each be paid by the United States compensation in the sum of —— dollars per annum. Their necessary transportation and travelling expenses shall be provided for as are those of officers of the army and navy when travelling on public business or duty, to be paid out of the appropriations for the services under their supervision.

The commission shall meet in Washington, D.C., for the transaction of business, not less than four times a year; but the president of the commission may convene it whenever in his judgment the exigencies of the service require a meeting.

The commission shall be attached to the office of the secretary of the department of ——, and under his superintendence shall exercise a general control over the plans of work of the coast and geodetic survey, the geological survey, and the meteorological service, and shall have the charge and custody of all the archives, books, documents, drawings, models, returns, apparatus, instruments, and all other things appertaining to the commission.

The estimates of the heads of these bureaus or offices shall pass through the commission for revision and approval; and, after the annual appropriations have been made, no money shall be expended under them, except after revision and approval by the commission of projects submitted by these bureaus in compliance with such projects.

If at any time public money is being spent by any of these bureaus, not in accordance with the views of the commission, the commission shall notify the proper auditor of the fact.

THE ADMINISTRATION OF THE SCIENTIFIC WORK OF THE GENERAL GOVERNMENT.¹

IN response to your oral request at the session of yesterday to present to the commission my "opinions relating to the organization of the scientific work of the government on a comprehensive plan, by which the work can be more thoroughly co-ordinated, more systematically prosecuted, and more economically administered, than at present," I beg leave to make the following statement:—

The scientific works prosecuted under the general government of the United States, and in like manner prosecuted by other nations, may broadly, but with sufficient accuracy, be classed under two heads. In the first class are constructive works, such as the erection of public buildings, the improvement of rivers and harbors, and the construction of light-houses. In all of the operations of this class, in order that the work may be properly executed, scientific principles and methods must be observed; but such works chiefly involve problems of applied science. The second class of operations in which the government of the United States, like all other civilized nations, is engaged, involve in their nature original investigation. They are designed, in large part, to furnish needed information to the people; and they not only involve questions of applied science, but, that the purpose for which they are prosecuted may be properly accomplished, new facts and principles must be discovered. Such institutions are the geological survey, the coast and geodetic survey, the signal-service or meteorological bureau, the fish-commission, the national museum, the hydrographic bureau, and the national observatory. The functions of such bureaus cannot properly be performed without scientific research, and their value depends upon the wisdom and efficiency of the methods of investigation pursued. It is to this second class, of purely scientific institutions, designed for and necessarily comprehending original research for the purpose of giving information to the people, that I confine my remarks.

The operations of such institutions are exceedingly complex, and, from their very nature, cannot be antecedently planned and executed according to such original plan. At every step of the work, plans must necessarily be modified, as necessitated or suggested by discovered facts. It is therefore impossible by law to organize such operations; and, more, it is impossible for the directors or superintendents of such work to lay out plans of operations which shall be a full guide to their assistants. A clear conception of the object to be attained, and a comprehensive knowledge of the principles to be used in the guidance of research, are necessary; and beyond that, from time to time, as facts are discovered, and the avenues of investigation are opened, the work is directed in its details. It will thus be seen that it is

¹ From the testimony of Major J. W. POWELL, director of the U. S. geological survey, before a joint committee of both houses of congress.